BY ORDER OF THE COMMANDER

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Air Force Space Command

SPACE AND MISSILE SYSTEMS CENTER STANDARD

SPACE SYSTEMS – FLIGHT PRESSURIZED SYSTEMS

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FOREWORD

1. This standard defines the Government's requirements and expectations for contractor performance in defense system acquisitions and technology developments.

2. This revised SMC standard comprises the text of The Aerospace Corporation report number TOR-2003(8583)-2896, Rev A, entitled *Space Systems – Flight Pressurized Systems* and contains the following major changes:

- Integrated requirements of Mil Std 1522A, Standard General Requirements of Safe Design and Operation of Pressurized Missile and Space systems chapter 4: General Design Requirements
- Integrated requirements of Mil Std 1522A, Standard General Requirements of Safe Design and Operation of Pressurized Missile and Space Systems chapter 6: Pressurized Systems Requirements

3. Beneficial comments (recommendations, changes, additions, deletions, etc.) and any pertinent data that may be of use in improving this standard should be forwarded to the following addressee using the Standardization Document Improvement Proposal appearing at the end of this document or by letter:

Division Chief, SMC/EAE
SPACE AND MISSILE SYSTEMS CENTER
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245

4. This standard has been approved for use on all Space and Missile Systems Center/Air Force Program Executive Office - Space development, acquisition, and sustainment contracts.

DAVID E. SWANSON, COL, USAF
SMC Chief Engineer

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TABLES

1. INTRODUCTION

1.1 Scope

This document establishes the baseline requirements for the design, fabrication, assembly, installation, test, inspection, operation, and maintenance of pressure systems used in spacecraft and launch vehicles. It deals primarily with the interfaces between the pressure vessel(s), or pressurized structures, and the corresponding pressure components within a specific pressure system; and interfaces between a pressure system and other spacecraft or launch vehicle systems. These requirements, when implemented on a specific pressure system, will assure a high level of confidence in achieving safe and reliable operation.

1.2 Application

This document is applicable to all pressure systems installed and operated in spacecraft, launch vehicles, and other space systems. The pressure vessels and/or pressurized structures with the associated pressure components, including lines, fittings, valves, bellows, and hoses, shall be designed and tested per the requirements specified in the industry standards ANSI/AIAA S-080 and S-081A, as appropriate.

The requirements specified in this document may be tailored for specific programs with the approval of the appropriate approval authority.

2. REFERENCED DOCUMENTS

The latest issue of the following are references for establishing pressurized system designs, analyses, demonstrations, and tests.

2.1 Government Documents

DOT/FAA/AR-MMPDS-01	Metallic Materials Properties Development Standardization (MMPDS)
MIL-E-6051	Electromagnetic Compatibility Requirements Systems
MIL-S-8512	Support Equipment, Aernautical, Special, General Specification for the Design of
MIL-STD-1472	Military Standard, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-E-6051	Electromagnetic Compatibility Requirements
NSS 1740.15	NASA Safety Standard for Oxygen and Oxygen Systems
NSS 1740.16	NASA Safety Standard for Hydrogen and Hydrogen Systems
SMC-TR-06-11 (AKA TR-2004(8583)-1)	Test Requirements for Launch, Upper-Stage, and Space Vehicles
CINDAS/USAF	Aerospace Structural Metals Handbook

2.2 Non-Government Documents

ANSI/AIAA S-080-1998	Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
ANSI/AIAA S-081A-2006	Space Systems – Composite Overwrapped Pressure Vessels (COPVs)

The Standards of the Hydraulic Insititute

3. VOCABULARY

3.1 Abbreviations and Acronyms

COPV Composite Overwrapped Pressure Vessel

MAWP Maximum Allowable Working Pressure

MDOP Maximum Design Operating Pressure

MEOP Maximum Expected Operating Pressure

MOP Maximum Operating Pressure

NDE Nondestructive Evaluation

NDI Nondestructive Inspection

QA Quality Assurance

3.2 Definitions

The following definitions of significant terms are provided to ensure precision of meaning and consistency of usage. In the event of a conflict, the definitions listed here apply.

A-Basis Allowable: The mechanical strength or strain values such that 99% of the population will meet or exceed the specified values with a confidence level of 95%.

Applied Load (Stress): The actual load (stress) imposed on the pressurized hardware item in the service environment.

B-Basis Allowable: The mechanical strength values such that 90% of the population will meet or exceed the specified values with a 95% confidence level.

Burst Pressure: The real pressure level at which rupture or unstable fracture of the pressurized hardware item occurs.

Component: A functional unit that is viewed as an entity for the purpose of analysis, manufacturing, maintenance, or recordkeeping.

Design Burst Pressure: A pressure that the pressurized hardware must withstand without rupture in the applicable operating environment. It is equal to the product of the maximum expected operating pressure (MEOP) and a design ultimate (burst) factor.

Design Safety Factor: A multiplying factor to be applied to limit loads and/or MEOP for purposes of analytical assessment and/or test verification of structural adequacy.

Detrimental Deformation: The structural deformation, deflection, or displacement that prevents any portion of the structure from performing its intended function, or that reduces the probability of successful completion of the mission.

Fittings: Components of a pressurized system utilized to connect lines, other pressure components and/or pressure vessels within the system.

Hazard: An existing or potential condition that can result in an accident.

Hydrogen Embrittlement: A mechanical-environmental failure process that results from the initial presence or absorption of excessive amounts of hydrogen in metals, usually in combination with residual or applied tensile stresses.

Limit Load: The maximum expected external load or combination of loads, that a structure may experience during the performance of specified missions in specified environments. When a statistical estimate

is applicable, the limit load is that load not expected to be exceeded at 99% probability with 90% confidence.

Lines: Tubular pressure components of a pressurized system provided as a means for transferring fluids between components of the system. Flexhoses are included in this document.

Loading Spectrum: A representation of the cumulative loading anticipated for the hardware under all expected operating environments. Significant transportation and handling loads are included.

Maximum Allowable Working Pressure (MAWP): The maximum pressure at which a component can continuously operated based on allowable stress values and functional capabilities. MAWP is synonymous with Maximum Design Operating Pressure (MDOP) or "Rated Pressure".

Maximum Expected Operating Pressure (MEOP): The maximum pressure the pressurized hardware is expected to experience during its service life in association with its applicable operating environments. MEOP includes the effect of temperature, transient peaks, maximum regulator pressure, and relief valve tolerance. MEOP is synonymous with maximum operating pressure (MOP).

Pressure Component: A component in a pressurized system, other than a pressure vessel, pressurized structure, or special pressurized equipment that is designed largely by the internal pressure. Examples are lines, fittings, gauges, valves, bellows, and hoses.

Pressure Vessel: A component of a pressurized system designed as a container designed that stores pressurized fluids and:

1) Contains stored energy of 14,240 ft-lb or greater, based on adiabatic expansion of a perfect gas; or
2) Contains gas or liquid which will create a mishap (accident) if released; or
3) Will experience a MEOP greater than 100 psi.

Pressurized Structures: Structures designed to carry both internal pressure and vehicle structural loads. The main propellant tank of a launch vehicle is a typical example.

Pressurized System: A system that consists of pressure vessels, or pressurized structures, or both, and other pressure components such as lines, fittings, valves, and bellows that are exposed to and structurally designed largely by the acting pressure. Not included are electrical or other control devices required for system operation. Pressurized system is synonymous with pressure system.

Proof Factor: A multiplying factor applied to the limit load or MEOP to obtain proof load or proof pressure for use in the acceptance testing.

Proof Pressure: The proof pressure is used to give evidence of satisfactory workmanship and material quality and/or establish maximum initial flaw sizes for safe-life demonstration. It is equal to the product of MEOP and a proof factor.

Service Life: The period of time (or cycles) starting with the manufacturing of the pressurized hardware and continuing through all acceptance testing, handling, storage, transportation, launch operations, orbital operations, refurbishment, retesting, reentry or recovery from orbit, and reuse that may be required or specified for the flight pressure system.

Ultimate Load: The product of the limit load and the ultimate design safety factor. It is the load, that the structure must withstand without rupture or collapse in the expected operating environments.

4. GENERAL REQUIREMENTS

This section presents general requirements for pressurized systems in terms of: (a)design, analysis, material selection and characterization, fabrication and process control; (b) quality assurance, operation and maintenance, including repair, and refurbishment; and, (c)storage. The specific requirements for hydraulic systems and pneumatic systems are presented in Section 6.

4.1 System Analysis Requirements

4.1.1 System Pressure Analysis

A thorough analysis of the pressurized system shall be performed to establish the correct MEOP, leak rates, etc. The effect of each of the component operating parameters on the MEOP shall be determined. When applicable, pressure regulator lock-up characteristics, valve actuation, and water hammer shall be considered for the entire service life of the pressure system*.

*: Throughout this document, limit load and MEOP are used as the baseline external load and internal pressure.

4.1.2 System Analysis

A detailed system functional analysis of the pressurized system shall be performed to determine that the operation, interaction, and sequencing of components within the pressurized system are capable of supporting all required actions and shall not lead to unsafe conditions, which could cause personnel injury or major damage to the vehicle, its booster, or other associated flight hardware and ground equipment. The analysis shall identify any single malfunction, software error, or personnel error in the operation of any component that may create conditions leading to an unacceptable risk to operating personnel or equipment. The analysis shall also evaluate any secondary or subsequent occurrence, failure, component malfunction, or software errors initiated by a primary failure that could result in personnel injury. Such items identified by the analysis shall be designated safety critical and shall require the following considerations:

a) Specific Design Action
b) Specific Safety Operating Requirements
c) Specific Hazard Identification and Proposed Corrective Action
d) Special Safety Supervision

4.1.2.1 System Analysis Data

System analysis data shall show that:

a) The system provides the capability of maintaining all pressure levels in a safe condition in the event of interruption of any process or control sequence at any time during test or countdown.

b) Redundant pressure relief devices have mutually independent pressure escape routes during all stages of operation.

c) In systems where pressure regulator failure may involve critical hazard to the crew or mission successs, regulation is redundant and where passive redundant systems are used includes automatic switchover.

d) When the hazardous effects of safety critical failures or malfunctions are prevented through the use of redundant components or systems, it shall be mandatory that all such redundant components or systems are operational prior to the initiation of irreversible portions of safety critical operations or events.

4.1.3 System Hazard Analysis

A system hazard analysis shall be performed on all hazardous pressurized system hardware, to identify hazards to personnel and facilities. All prelaunch and launch operations and conditions shall be included in the analysis. The results of the system functional analysis shall be used in the system hazard analysis to ensure that all operations and configurations are accounted for in the system hazard analysis.

Hazards identified by the analysis shall be designated safety-critical and shall require mitigation by one or more of the following:

a) Design modifications to eliminate the hazard.

b) Operating restrictions to minimize personnel exposure during hazardous periods.

c) Specific hazard identification and procedural restrictions to avoid hazardous conditions.

d) Special safety supervision during hazardous operations and systems configurations.

4.2 Design Requirements

The general design requirements for a pressurized system are delineated in the following sections.

4.2.1 Loads, Pressures, and Environments

The entire anticipated load-pressure-temperature history and associated environments throughout the service life of the pressurized system shall be determined in accordance with specified mission requirements. As a minimum, the following factors and their statistical variations shall be considered as appropriate:

a) The environmentally induced loads and pressures.

b) The environments acting simultaneously with these loads and pressures with their proper relationships.

c) The frequency of application of these loads, pressures, environments, and their levels and duration.

These data shall be used to define the design spectra, which shall be used for both design analysis and testing. The design spectra shall be revised as the structural design develops and the loads analysis matures.

4.2.2 Strength

All pressure components within the pressurized system including component interfaces, attachments, tie-downs, and other critical points shall possess sufficient strength to withstand limit loads and MEOP in the expected operating environments throughout the service life without experiencing detrimental deformation. It shall sustain system-level proof pressure without incurring gross yielding or detrimental deformation. It shall also withstand ultimate loads and design burst pressure in the expected operating environments without experiencing rupture or collapse.

For pressure vessels and pressurized structures, requirements set forth in ANSI-AIAA S-080 and S-081A shall be met.

The margin of safety shall be positive and shall be determined by analysis or test at design ultimate and design limit levels, when appropriate, at the temperatures expected for all critical conditions.

4.2.3 Stiffness

The mounting and arranging of all components in the pressurized system shall provide adequate stiffness to limit resonant response, and to prevent excess stresses at the interface between components and at mounting brackets when subjected to the combined effects from limit loads, MEOP, and deflections of the supporting structures in the expected operating environments. Sufficient compliance shall be provided between connected components to prevent excessive stresses at their interfaces from the combined effects of limit loads, MEOP, and deflections of the supporting structures in the expected operating environments.

4.2.4 Thermal Effects

Thermal effects, including heating and cooling rates, temperatures, thermal gradients, thermal stresses and deformations, and changes with temperature of the physical and mechanical properties of the material of construction, shall be factored into the design of the flight pressure system. Thermal effects shall be based on temperature extremes that simulate those predicted for the operating environment plus a design margin as specified in SMC-TR-06-11 (aka The Aerospace report, TR-2004(8583)-1 Rev.A.)

4.2.5 Stress Analysis

A detailed and comprehensive stress analysis of each pressurized system design shall be conducted to verify the hardware strength and stiffness, with the assumption that no crack-like flaws exist in the hardware. The analysis shall determine stresses resulting from the combined effects of internal pressure, ground or flight loads, temperatures, and thermal gradients. Both membrane stress and bending stress resulting from internal pressure and external loads shall be calculated as appropriate to account for the effects of geometrical discontinuities, design configuration, and structural support attachments. The analysis shall include the effects of adding stresses from restraints, manufacturing tolerances, test conditions, residual stresses, and assembly stresses. Thermal effects, including heating rates, temperatures, thermal gradients, thermal stresses and deformations, and changes in the physical and mechanical properties of the materials due to environmental factors, shall be considered in the stress analysis.

Loads shall be combined by using the appropriate design safety factors on the individual load and the results shall be compared to allowable loads. Design safety factors on external (support) loads shall be as assigned to the primary structure(s) supporting the pressurized system. The effects of flexure of lines, pressure vessels, and supporting structures being acted on by the loads, pressures, and environments shall be accounted for in the analysis.

Classical solutions, finite element methods, or other proven equivalent structural analysis techniques shall be used to calculate the stresses, strains, and displacements. Minimum material gages as specified in the design drawing shall be used in the stress analysis. The allowable material strength shall reflect the effects of temperature, thermal cycling and gradients, processing variables, and time associated with the design environments. The effect of thickness gradients and variations in material thickness and manufacturing-process parameters, as specified in the design documentation, shall be used in the stress analysis. Variations in manufacturing and other design tolerances shall be accounted for.

Evaluation of buckling strength shall consider the combined action of primary and secondary stresses and their effects on general instability, local or panel instability, and cripping.

Minimum margin of safety associated with the parent materials, weldments and heat-affected zones shall be calculated and tabulated for all critical locations of the pressurized system along with their stress

levels. The margin of safety shall be positive against the strength and stiffness requirements of Section 4.2.2 and 4.2.3, respectively.

Records of the stress analysis shall be maintained. The records shall include the input parameters, data, assumptions, rationales, methods, references, and summary of significant analysis results. The analysis shall be revised and updated to maintain currency for the life of the program.

4.2.6 Fatigue Analysis

In addition to the stress analysis, conventional fatigue-life analysis shall be performed, as appropriate, on the unflawed pressurized system. Nominal values of fatigue-life (S-N) data shall be taken from reliable sources such as DOT/FAA/AR-MMPDS-01, *Metallic Materials Properties Development Standardization (MMPDS)* and the *Aerospace Structural Metals Handbook*, or other sources approved by the procuring agency. A scatter factor of four (4) shall be applied to the service life. The limit for accumulated fatigue damage using Miner's Rule shall be 80% of the normal limit, i.e., $\Sigma n/N \leq 0.8$.

4.3 Material Requirements

4.3.1 Metallic Materials

Metallic materials used in the assembly and installation of a specific pressurized system shall be selected, evaluated, and characterized to ensure all system requirements are met.

4.3.1.1 Metallic Material Selection

Metallic materials shall be selected on the basis of proven environmental compatibility, material strength, and fatigue characteristics. Unless otherwise specified, the material's "A" basis allowable shall be used in any application where failure of a single load path would result in loss of structural integrity to any part of the pressurized system. For applications where failure of a redundant load path would result in a safe redistribution of applied loads to other load carrying members, the material's "B" basis allowable may be used.

4.3.1.2 Metallic Material Evaluation

The selected metallic materials shall be evaluated with respect to material processing, fabrication methods, manufacturing operations, refurbishment procedures and processes, and other factors that affect the resulting strength and fracture properties of the material in the fabricated as well as the refurbished configurations.

The evaluation shall ascertain that the mechanical properties, strengths, and fatigue properties used in design and analyses will be realized in the actual hardware and that these properties are compatible with the fluid contents and the expected operating environments. Materials which are susceptible to stress-corrosion cracking or hydrogen embrittlement shall be evaluated by performing sustained-load fracture tests when applicable data is not available.

4.3.1.3 Metallic Material Characterization

The allowable mechanical and fatigue properties of all selected metallic materials shall be obtained from reliable sources such as DOT/FAA/AR-MMPDS-01, *Metallic Materials Properties Development Standardization (MMPDS)*, and other sources approved by the procuring agency. Where material properties are not available, they shall be determined by test methods approved by the procuring agency.

4.3.2 Non -metallic Material Requirements

4.3.2.1 Composite Materials

4.3.2.1.1 Composite Material Selection

Composite materials used for a part in a specific pressurized system shall be selected on the basis of environmental compatibility, material strength/modulus, and stress-rupture properties. The effects of fabrication process, temperature/humidity, load spectra, and other conditions, that may affect the strength and stiffness of the material in the fabricated configuration, shall also be included in the rationale for selecting the composite materials.

4.3.2.1.2 Composite Material Evaluation

The materials selected for a composite part shall be evaluated with respect to the material processing, fabrication methods, manufacturing operations and processes, operating environments, service life and other pertinent factors that affect the resulting strength and stiffness properties of the material in the fabricated configurations.

4.3.2.1.3 Composite Material Characterization

The properties of the composite materials selected shall be characterized in their expected operating environments. Test methods employing samples representative of the manufacturing processes involved in the pressurized systems hardware fabrication and accounting for residual stresses shall be employed for determining material properties as required. The test specimens and procedures utilized shall follow standardized test methods whenever available in order to provide valid test data for the intended application.

A composite material's strength allowable shall be determined from testing of coupon, subscale or full-scale composite parts. When subscale and coupon data are used in the database, correlation between coupon/subscale data and full-scale data shall be established.

4.3.2.2 Polymeric Materials

4.3.2.2.1 Polymer Material Selection

Polymeric materials used for a part or for joining parts in the pressurized system shall be selected on the basis of environmental compatibility, material strength/modulus, fatigue, creep deformation/relaxation, stress-rupture properties, and suitability as an adhesive, as dictated by the application. The effects of fabrication process, temperature/humidity, load spectra, and other conditions that may affect the strength, stiffness, and dimensional tolerance of the material in the fabricated configuration shall also be included in the rationale for selecting the polymeric materials.

4.3.2.2.2 Polymer Material Evaluation

The materials selected for a polymeric part in the pressurized system shall be evaluated with respect to the material processing, manufacturing operations and processes, operating environments, service life, and other pertinent factors that affect the resulting strength, stiffness, and dimensional tolerance properties of the material in the fabricated configurations.

4.3.2.2.3 Polymer Material Characterization

The properties of the polymeric materials selected shall be characterized in their expected configurations and operating environments. Test methods employing samples representative of the manufacturing processes involved in a specific pressurized system hardware fabrication shall be employed for determining material properties, as required. The test specimens and procedures utilized shall follow

standardized test methods (such as those published by ASTM) whenever available in order to provide valid test data for the intended application.

A polymeric material's strength allowable shall be determined from testing of coupon, subscale or full-scale composite parts. When subscale and coupon data are used in the database, correlation between coupon/subscale data and full-scale data shall be established.

4.4 Fabrication and Process Control Requirements

Proven processes and procedures for fabrication and repair shall be used to preclude damage or material degradation during material processing, manufacturing operations, and refurbishment. In particular, special attention shall be given to ascertain that the melting, welding, bonding, forming, joining, machining, drilling, grinding, repair, etc., processes as applied to joining system components and hardware and attaching hardware are within the state-of-the-art and have been used on similar hardware.

The mechanical and physical properties of the parent materials, weld-joints and heat-affected zones shall be within established design limits after exposure to the intended fabrication processes. The machining, forming, joining, welding, dimensional stability during thermal treatments, and through-thickness hardening characteristics of the material shall be compatible with the fabrication processes to be encountered.

Special precautions shall be exercised throughout the manufacturing operations to guard against processing damage or other structural degradation.

Bonding, clamping, and joining at the interfaces and mountings of the flight pressure systems shall all be controlled to ensure that all requirements are met.

4.5 Contamination Control and Cleanliness Requirements

Required levels of contamination control shall be established by the actual cleanliness needs and the nature of the flight pressure system and its components. Contamination includes solid, liquid, and gaseous material unintentionally introduced into the system. General contamination control requirements are as follows:

a) The design shall provide protection from contaminants by adequate filtration, sealed modules, clean fluids, and clean environment during assembly, storage, installation, and use.
b) The design shall allow for verification that the lines and components are clean after flushing and purging.
c) The design shall ensure that contaminants and waste fluids can be flushed and purged.

The following considerations shall be factored into the design of flight pressure systems to minimize and effectively control contamination:

a) Contamination shall be prevented from entering or developing within the system.

b) The system shall be designed to include provisions to detect contamination.

c) The system shall be designed to include provisions for removal of contamination and provisions for initial purge with fluid or gas that will not degrade future system performance.

d) The system shall be designed to be tolerant of contamination.

e) All pressurizing fluids entering the safety critical system shall be filtered through a 10 micron or finer filter, before entering the system;

f) All pressure systems shall have fluid filters in the system, designed and located to reduce the flow of contaminant particles to a safe minimum.

g) All of the circulating fluid in the system shall be filtered downstream from the pressure pump, or immediately upstream from safety critical actuators.

h) Entrance of contamination at test points or vents shall be minimized by downstream filters.

i) The bypass fluid or case drain flow on variable displacement pumps shall be filtered.

j) When the clogging of small orifices could cause a hazardous malfunction or failure of the system, they shall be protected by a filter element designed to prevent clogging of the orifice. Note that this includes servo valves.

4.6 Quality Assurance Program Requirements

A quality assurance (QA) program shall be established to ensure that the product and engineering requirements, drawings, material specifications, process specifications, workmanship standards, design review records, failure mode analysis, nondestructive inspection (NDI), and acceptance tests are effectively used to ensure that the completed flight pressure system meets its specified requirements. The program shall ensure that: (a) materials, parts, subassemblies, assemblies, and all completed and refurbished hardware conform to applicable drawings and process specifications; (b) that no damage or degradation has occurred during material processing, fabrication, inspection, acceptance testing, shipping, storage, operational use and refurbishment; and (c) that defects that could cause failure are detected, evaluated, and corrected.

4.6.1 Inspection Plan Requirements

An inspection master plan shall be established prior to start of system assembly and installation. The plan shall specify appropriate inspection points and inspection techniques for use throughout the program, beginning with material procurement and continuing through fabrication, assembly, acceptance test, operation, and refurbishment, as appropriate. In establishing inspection points and inspection techniques, consideration shall be given to the material characteristics, fabrication processes, design concepts, and structural configuration. Acceptance and rejection criteria shall be established as part of the plan for each phase of inspection and for each type of inspection.

4.6.2 Inspection Technique Requirements

Inspections shall include both visual inspection (with appropriate magnification) and NDI, as necessary.

4.6.3 Inspection Data Requirements

At a minimum, inspection data shall be dispositioned as follows:

a) Inspection data in the form of flaw histories shall be maintained throughout the life of the flight pressure system.
b) This data shall be periodically reviewed and assessed to evaluate trends and anomalies associated with the inspection procedures, equipment and personnel, material characteristics, fabrication processes, design concept, and structural configuration.
c) The result of this assessment shall form the basis of any required corrective action.

4.6.4 Acceptance Test Requirements

All newly assembled flight pressurized systems shall pass a proof-pressure test, a leak test, a bonding and grounding test, and a functional test, in that order, prior to first use. This test sequence shall be repeated after arrival at the launch processing facility.

4.6.4.1 Proof-Pressure Test Requirements

The flight pressurized system shall be tested at the system proof-pressure level prior to first use. For systems with zones operating at different pressures, each zone shall be tested to its proof pressure level. Proof- pressure testing shall demonstrate that the flight pressure system will sustain proof pressure without distortion, damage, leakage, or loss of functionality. If the system includes relief valves and/or burst disks, proof testing shall be performed in those zones/sections without the relief valves and/or burst disks. There shall be interface connections to the relief valves and/or burst disks that may not be proof tested.

The minimum proof-test factor and the corresponding design burst-test factor for typical pressure vessels, pressurized structures and pressure components (including lines and fittings, fluid return sections, fluid return hoses) are shown in Table 4-1.

Table 4-1 Minimum Test Factors for Components in Pressurized Systems

Type of Components		Proof	Design Burst
Pressure vessel		1.25	1.5
Pressurized structure		1.10	1.25
Line and fitting	diameter < 1.5 in	1.5	4.0
	diameter ≥ 1.5 in.	1.5	2.5
Fluid Return section		1.5	3.0
Fluid Return Hose		1.5	5.0
Other Pressure components		1.5	2.5

Note: 1. MEOP is the baseline external and internal pressure
2. Pressure components subject to low or negative pressures shall be evaluated at 2.5 times MEOP during service life.

4.6.4.2 Leak Test Requirements

The flight pressurized system shall be leak tested at the system MEOP prior to first use. For systems with zones operating at different pressures, each zone shall be at its MEOP for the leak test. The gas used during the leak test shall be the same as the system operating fluid to the best extent possible. For systems or zones intended to be filled with a liquid, a suitable leak check gas shall be used.

For systems intended to operate with hazardous fluids, a nonhazardous gas may be substituted. All mechanical connections, gasket joints, seals, weld seams, and other items susceptible to leakage shall be tested. The leak rates through fill and drain valves, thruster valves, and pressure relief valves shall be measured and verified within specification. Any method demonstrated capable of detecting and/or measuring leakage is acceptable.

4.7 Qualification Test Requirements

Internal/external pressure testing shall be conducted on all pressure components to demonstrate no failure at the design burst pressure. Other environmental qualification tests shall be conducted as required by SMC-TR-06-11 (AKA TR-2004(8583)-1. Qualification testing is not required for lines and fittings that are fabricated using common aerospace materials and manufacturing processes.

4.8 Operation and Maintenance Requirements

4.8.1 Operating Procedure

Operating procedures shall be established for the pressurized system. The procedures shall be compatible with the safety requirements and personnel control requirements at the facility where the operations are conducted. Step-by-step directions shall be written with sufficient detail to allow a qualified technician or mechanic to accomplish the operations. Schematics that identify the location and pressure limits of all components and their interconnections into a system shall be included in the procedure or be made available at the time it is run.

Prior to initiating or performing a procedure involving hazardous operations with flight-pressure systems, practice runs shall be conducted on nonpressurized systems until the operating procedures are well rehearsed. Initial tests shall then be conducted at pressure levels not to exceed 50 percent of the normal operating pressures until operating characteristics can be established and stabilized. Only qualified and trained personnel shall be assigned to work on or with high pressure systems. Warning signs identifying the hazards shall be posted at the operations facility prior to pressurization.

4.8.2 Safe Operating Limit

Safe operating limits shall be established based on the pressure capabilities of all components and the effects of assembly into a completed system. For flight pressure systems with several regions operating at different pressure levels, safe operating levels shall be established for each region. The safe operating limits shall be summarized in a format that will provide rapid visibility of the important structural characteristics and capability of the flight pressure system.

4.8.3 Inspection and Maintenance

The results of the stress analysis and the fatigue-life analysis shall be used in conjunction with the appropriate results from the structural development and qualification tests to develop a quantitative approach to inspection and repair.

The allowable damage limits for each component of the flight pressure system shall be used to establish the required inspection interval and repair schedule to maintain the hardware to the requirements of this document. Procedures shall be established for recording, tracking, and analyzing operational data as it is accumulated to identify critical areas requiring corrective actions. Analyses shall include prediction of remaining life and reassessment of required inspection intervals.

4.8.4 Repair and Refurbishment

When inspections reveal structural damage or defects exceeding permissible levels, the damaged hardware shall be repaired, refurbished, or replaced, as appropriate. All repaired or refurbished flight pressure systems shall be recertified after each repair and refurbishment to verify their structural integrity and to establish their suitability for continued service.

4.8.5 Storage

A flight pressure system put into storage shall be protected against exposure to adverse environments that could cause corrosion or other forms of material degradation. It shall be protected against mechanical degradation resulting from scratches, dents, or accidental dropping of the hardware. Induced stresses due to storage fixture constraints shall be minimized by suitable storage fixture design. In the event storage requirements are violated, recertification shall be required prior to return to use.

4.8.6 Documentation

Inspection, maintenance, and operation records shall be kept and maintained throughout the life of the flight pressure system. As a minimum, the records shall contain the following information:

a) Temperature, pressurization history, and pressurizing fluid for both tests and operations.

b) Numbers of pressurizations experienced as well as number allowed in safe-life analysis.

c) Results of any inspection conducted, including: inspector, inspection dates, inspection techniques employed, location and character of defects, defect origin and cause. This shall include inspections made during fabrication.

d) Storage condition.

e) Maintenance and corrective actions performed from manufacturing to operational use, including refurbishment.

f) Sketches and photographs to show areas of structural damage and extent of repairs.

g) Acceptance and recertification test performed, including test conditions and results.

h) Analyses supporting the repair or modification that may influence future use capability.

4.8.7 Reactivation

A flight pressure system reactivated for use after a period in either an unknown, unprotected, or unregulated storage environment shall be recertified to ascertain its structural integrity, functionality, and suitability for continued service before first use.

4.8.8 Recertification

Any flight pressure system requiring recertification prior to return to service shall meet the following requirements:

a) The documentation of affected components or portions of the flight pressure system shall be reviewed to establish its last known condition.

b) It shall be inspected and subjected to appropriate NDI to detect any previously unknown flaws.

c) It shall pass all the acceptance test requirements for a new system in accordance with Section 4.6.4.

4.8.8.1 Test after Limited Modification and Repair

If any system element such as valves, regulators, gauges, or tubing has been disconnected or reconnected for any reason, the affected system or subsystem shall be leak tested. For more extensive modification or repair that may affect its ability to meet the requirements of this document or its required functions, the flight pressurized system shall meet the full recertification requirements.

5 GENERAL PRESSURIZED SYSTEM REQUIREMENTS

5.1 Design Features

5.1.1 Assembly

Components shall be designed so that, during the assembly of parts, sufficient clearance exists to permit assembly of the components without damage to the O-rings or backup rings where they pass threaded parts or sharp corners.

5.1.2 Routing

Straight tubing and piping runs between two rigid connection points shall be avoided. Where such straight runs are necessary, provision shall be made for expansion joints, motion of the units, or similar compensation to ensure that no excessive strains are applied to the tubing and fittings. Line bends shall be used to ease stresses induced in tubing by alignment tolerance and vibration.

5.1.3 Separation

Redundant pressure components and systems shall be physically separated from main systems for maximum advantage in case of damage or fire.

5.1.4 Shielding

Pressurized systems shall be shielded from other systems when required to minimize all hazards caused by proximity to combustible gases, heat sources, electrical equipment, etc. Any failure in any such adjacent systems shall not result in combustion or explosion of pressure fluids or components. Lines, drains, and vents shall be shielded or separated from other high-energy systems; for example, heat, high voltage, combustible gases, and chemicals. Drain and vent lines shall not be connected to any other lines in any way that could generate hazardous substances from the components being drained or vented. Pressure fluid reservoirs shall be shielded or isolated from combustion apparatus or other heat sources.

5.1.5 Grounding

Hydraulic system components and lines shall be electrically grounded to metallic structures.

5.1.6 Handling

Fixtures for safe handling and hoisting with coordinated attachment points in the system structure shall be provided. Handling and hoisting loads shall be in accordance with MIL-S-8512.

5.1.7 Special Tools

Safety-critical pressurized systems shall be designed so that special tools shall not be required for removal and replacement of components unless it can be shown that the use of special tools is unavoidable.

5.1.8 Test Points

Test points, when required, shall be provided such that disassembly for test is not required. The test points shall be easily accessible for attachment of ground test equipment.

5.1.9 Common-Plug Test Connectors

Common-plug test connectors for pressure and return sections shall be designed to require positive removal of the pressure connection prior to unsealing the return connections.

5.1.10 Individual Pressure and Return Test Connectors

Individual pressure and return test connectors shall be designed to positively prevent inadvertent cross-connections.

5.1.11 Threaded Parts

All threaded parts in safety-critical components shall be securely locked to resist uncoupling forces by acceptable safe design methods. Safety wiring and self-locking nuts are examples of acceptable safe design. Torque for threaded parts in safety-critical components shall be specified.

5.1.12 Friction Locking Devices

Use of friction-type locking devices shall be avoided in safety-critical applications. Star washers and jam nuts shall not be used as locking devices.

5.1.13 Internally Threaded Bosses

The design of internally threaded bosses shall preclude the possibility of damage to the component or the boss threads because of screwing universal fittings to excessive depths in the bosses.

5.1.14 Retainer or Snap Rings

Retainer or snap rings shall not be used in a specific pressurized system where failure of the ring would allow connection failures or blowouts caused by internal pressure.

5.1.15 Snubbers

Snubbers shall be used with all Bourdon-type pressure transmitters, pressure switches, and pressure gages, except air pressure gages.

5.2 Component Selection

5.2.1 Connections

Pressure components shall be designed or selected to ensure that hazardous disconnections or reverse installations within the subsystem are not possible. Color codes, labels, and directional arrows are not acceptable as the primary means for preventing incorrect installation.

5.2.2 Fluid Temperature

The maximum fluid temperature shall be estimated early in design as part of data for selection of safety - critical components, such as system fluid, pressurizing gas, oil coolers, gaskets, etc.

5.2.3 Actuator Pressure Rating

Components shall be specified that are capable of safe actuation under pressure equal to the maximum relief valve setting in the circuit in which they are installed.

5.2.4 Pressure Service Rating

Pumps, valves/regulators, hoses, and all such prefabricated components of a pressure system shall have proven pressure service ratings equal to or higher than the limit pressure (MEOP) and rated service life of the system.

5.2.5 Pump Selection

The Standards of the Hydraulic Institute shall be applied in evaluating safety in pump selection.

5.2.6 Fracture and Leakage

Where leakage or fracture is hazardous to personnel or critical equipment, the component shall be designed so that failure occurs at the outlet threads of valves before the inlet threads or body of the valve fails under pressure.

5.2.7 Oxygen System Components

Specify valves and other pressure components for oxygen systems of 3,000 psi or higher that are slow opening and closing types to minimize the potential for ignition of contaminants. Such systems shall also require electrical groundings to eliminate the possibility of the build-up of static electrical charges.

5.2.8 Pressure Regulators

Pressure regulators to operate in the center 50 percent of their total pressure range shall be selected to avoid creep and inaccuracies at either end of the full operating range.

5.2.9 Flareless Tube Fittings

In all cases, flareless tube fittings shall be properly preset prior to pressure applications.

5.2.10 Manual Valves and Regulators

Manually operated valves and regulators shall be designed so that over-torquing of the valve stem or regulator adjustment cannot damage soft seats to the extent that failure of the seat will result. Valve designs that utilize uncontained seats are not acceptable and shall not be specified.

5.3 Design Pressures

5.3.1 Over or Under Pressure

Specify warning devices to indicate hazardous over- or under-pressure to operating personnel. These devices shall actuate at predetermined pressure levels designed to allow time for corrective action.

5.3.2 Back Pressure

Safety-critical actuation of pneumatic systems shall not be adversely affected by any back-pressure resulting from concurrent operations of other parts of the system under service conditions.

5.3.3 Pressure Isolation

Components or lines that can be isolated and contain residual pressure shall be equipped with gage readings and bleed valves that are available in the system for pressure safety check. Bleed valves shall be directed away from operating personnel. Fittings or caps for bleeding pressure are not acceptable.

5.3.4 Gas/Fluid Separation

Pressurized reservoirs that are designed for gas/fluid separation with provision to entrap gas that may be hazardous to the system or safety-critical actuation, and prevent its recirculation into the system, shall be specified. This shall include the posting of instructions adjacent to the filling point for proper bleeding when servicing.

5.3.5 Compressed Gas Bleeding

Compressed gas emergency systems shall be bled directly to the atmosphere away from the vicinity of personnel, rather than into a reservoir. If the gas is combustible, consideration shall be given to methods for reducing the potential for accidental ignition or explosion.

5.4 Design Loads

5.4.1 Acceleration and Shock Loads

All lines and components shall be installed to withstand all expected acceleration and shock loads. Shock-isolation mounts may be used, if necessary, to eliminate destructive vibration and interference collisions.

5.4.2 Torque Loads

The mounting of components, including valves, shall be on structures having sufficient strength to withstand torque and dynamic loads. Only lightweight components that do not require adjustment after installation may be supported by the tubing, provided that a tube clamp is installed on each tube near the component.

5.4.3 Vibration Loads

Tubing shall be supported by cushioned-steel tube clamps or by multiblock-type clamps that are suitably spaced to restrain destructive vibration loads.

5.5 Controls

5.5.1 Interlocks

Specify interlocks where necessary to prevent a hazardous sequence of operations and provide a fail-safe capability at all times. For example, the "open" position of remotely controlled valves that can hazardously pressurize lines leading to remotely controlled (or automatic) disconnect couplings shall be interlocked to preclude the "open" valve position coincident with the disconnected condition of the couplings.

5.5.2 Multiple Safety Critical Functions

Pressure systems that combine several safety-critical functions shall have sufficient controls for isolating failed functions, for the purpose of safely operating the remaining functions.

5.5.3 Critical Flows and Pressures

Pressure systems shall have pressure-indicating devices to monitor critical flows, and pressures marked to show safe upper and lower limits of system pressure. The pressure indicators shall be so located as to be readily visible to the operating crew.

5.6 Protection

All systems with pressures above 500 psi in all areas where damage can occur during servicing or other operational hazards shall be protected. Hazardous piping line routes that invite use as handholds or climbing bars shall be avoided. Pressure lines and components of 500 psi or higher that are adjacent to safety critical equipment to protect such equipment in the event of leakage or burst of pressure systems shall be shielded.

5.7 Electrical

5.7.1 Hazardous Atmospheres

Electric components for use in potentially ignitable atmospheres shall be demonstrated to be incapable of causing an explosion in the intended application.

5.7.2 Radio Frequency Energy

Electrically energized hydraulic components shall not propagate radio-frequency energy that is hazardous to other subsystems in the total system, or interfere in the operation of safety critical electronic equipment as specified in MIL-E-6051.

5.7.3 Grounding

All pressure system components, including lines, to metallic structures shall be electrically grounded.

5.7.4 Solenoids

All solenoids shall be capable of safely withstanding a test voltage of not less than 1500 V rms at 60 cps for 1 minute between terminals and case at the maximum operating temperature of the solenoid in the functional envelope.

5.7.5 Electric Motor-Driven Pumps

Electric motor-driven pumps used in safety critical systems shall not be used for ground-test purposes unless the motor is rated for reliable continuous and safe operation.

5.8 Pressure Relief

5.8.1 General Requirements

Pressure relief devices on all systems having a pressure source that can exceed the MAP of the system, or where the malfunction/failure of any component can cause the MAP to be exceeded, shall be specified.

Relief devices are required downstream of all regulating valves and orifice restrictors unless the downstream system is designed to accept full source pressure. On space systems where operational or weight limitations preclude the use of relief valves, and systems that will operate in an environment not hazardous to personnel, relief valves can be omitted if the ground or support system contains such devices, they cannot be isolated from the airborne system during the pressurization cycle, and the space system cannot provide it own protection.

5.8.2 Flow Capacity

All pressure relief devices shall provide relief at full-flow capacity at 110% of the MEOP of the system, or lower.

5.8.3 Sizing

The size of pressure relief devices shall be specified to withstand maximum pressure and flow capacities of the pressure source, to prevent pressure exceeding 110% of the MEOP of the system.

5.8.4 Unmanned Flight Vehicle Servicing

For a ground system that is specifically designed to service an unmanned flight vehicle, pressure-relief protection shall be provided within the ground equipment, if no capability exists to isolate the pressure relief protection from the flight vehicle during the pressurization cycle.

5.8.5 Automatic Relief

5.8.5.1 Low Safety Factor

Where safety factors less than 2.0 are used in the design of flight pressure vessels, provide a means for the automatic relief, depressurization, and pressure verification of safety critical vessels in the event of launch abort.

5.8.5.2 Confinement

Whenever any pressure volume can be confined and/or isolated, provide an automatic pressure relief device. Pop-valves, rupture discs, blow-out plugs, armoring, and construction to contain the greatest possible overpressure that may develop are examples of corrective measures for system safety in cases not covered by the above paragraphs.

5.8.6 Venting

Vent pressure-relief devices for toxic or inert gases to safe areas or scrubbers, away from the vicinity of personnel.

5.8.7 Relief Valve Isolation

Shutoff valves for maintenance purposes on the inlet side of pressurized relief valves are permissible if a means for monitoring and bleeding trapped pressure is provided and the requirements of ASME Code, for unfired pressure vessels, Appendix M, UA 354, and the provisions for valve design in Section 4.3 are met. It is mandatory that the valve be locked open when the system is repressurized.

5.8.8 Negative Pressure Protection

5.8.8.1 Testing

Hydrostatic testing systems for vessels that are designed to sustain negative internal pressure shall be equipped with fail-safe devices for relief of hazardous negative pressure during the period of fluid removal. Check valves and valve interlocks are examples of devices that can be used for this purpose.

5.8.8.2 Storage and Transportation

Thin-walled vessels that can be collapsed by a negative pressure shall have negative pressure relief and/or prevention devices for safety during storage and transportation.

5.8.9 Reservoir Pressure Relief

Pressurized reservoirs shall be designed so that ullage volume shall be connected to a relief valve that shall protect the reservoir and power pump from hazardous overpressure or back pressure of the system.

5.8.10 Air Pressure Control

The air pressure control for pressurized reservoirs shall be an externally nonadjustable pressure regulating device. If this unit also contains a reservoir pressure relief valve, design the unit so that no failure in the unit will permit overpressurization of the reservoir.

5.9 Control Devices

5.9.1 Directional Control Valves

Safety-critical pressure systems shall be designed to incorporate two or more directional control valves to preclude the possibility of inadvertently directing the flow or pressure from one valve into the flow or pressure path intended for another valve, with any combination of valve settings possible in the total system.

5.9.2 Overtravel

Control devices shall be designed to prevent overtravel or undertravel that may contribute to a hazardous condition, or damage to the valve.

5.9.3 Pressure and Volume Control Stops

All pressure and volume controls shall have stops, or equivalent, to prevent setting outside their nominal safe working range.

5.9.4 Manually Operated Levers

Components that have integrated manually operated levers shall provide levers and stops capable of withstanding the limit torques specified by MIL-STD-1472; levers and stops on remote controls shall be provided to be capable of withstanding a limit torque of 1800 lb-in; sheathed flexible-actuators for valve controls in safety-critical pressure systems shall not be used.

5.9.5 Limit Torque

Control components that have integral manually operated levers shall provide levers and stops capable of withstanding the limit torques, as shown in Table 5-1.

Table 5-1 Limit Design Torque for Levers

Lever Radius, R in.	Design Torque, lb-in.
Less than 3	50 x R
3 to 6	75 x R
Over 6	150 x R

5.10 Accumulators

5.10.1 Accumulator Design

Accumulators shall be designed in accordance with the pressure vessel standards for ground systems and located for minimal probability of mechanical damage and for minimum escalation of material damage or personnel injury in the event of a major failure such as vessel rupture.

5.10.2 Accumulator Gas Pressure Gages

Accumulator gas pressure gages shall not be used to indicate system pressure for operational or maintenance purpose.

5.10.3 Accumulator Identification

Gas type and pressure level shall be posted on, or immediately adjacent to, the accumulator.

5.11 Flexhose

5.11.1 Installation

Flexhoses shall be used between any two connections where relative motion can be expected to fatigue metal tubes or pipes. Flexhose installation shall be designed to avoid abrasive contact with adjacent structure or moving parts. Rigid supports shall not be used on flexhoses.

5.11.2 Restraining Devices

Flexhose installations that are six feet long or greater shall be designed and installed so that restraint is provided on both the hose and adjacent structure at no greater than six-foot intervals and at each end to prevent whiplash in the event of a burst.

Restraining devices shall be designed to constrain a force not less than 1.5 times the open-line pressure force as calculated by the methods of Table 5-2. The design safety factor of the restraining device shall not be less than three (3). Sand or shot bags placed on top of flexhose is not an acceptable restraint. Hose –clamp-type restraining devices shall not be used.

Table 5-2 Open Line Force Calculation Factor

Diameter Opening (in.)	Calculated Force Factor for Each psi of Source Pressure (lb)
1/8	0.18506
1/5	0.2832
3/8	0.3814
1/2	0.4796
5/8	0.5777
3/4	0.6759
7/8	0.7741
1	0.8723

Note: To calculate the force acting on the line opening, select the applicable diameter and multiply the right-hand column by the source pressure (psi).

5.11.3 Flexhose Stress

Flexhose installations shall be designed such that no stress or strain of any nature in the hard lines or components can be produced. Stress induced because of dimensional changes caused by pressure or temperature variations, and torque forces induced in the flexhoses, shall be included.

5.11.4 Temporary Installations

Temporary installations using chains or cables anchored to substantial fixed points, lead ingots or other weights are acceptable providing they meet the requirements of Section 4.3.2.1. Protect flexhose from kinking or abrasive chafing from the restraining device or damage from adjacent structure or moving parts that may cause reduction in strength.

6. SPECIFIC REQUIREMENTS

This section presents specific requirements for hydraulic systems and pneumatic systems used in space vehicles and launch vehicles. All these pressurized systems shall also meet the general requirements of Section 4.

6.1 Hydraulic System Requirements

6.1.1 Hydraulic System Components

6.1.1.1 Component Integrity

When the system pressure profile is indeterminate, perform safety tests at pressures no lower than 67% of MAWP for components rated up to 3000 psig and no lower than 80% of the MAWP for components rated above 3000 psig.

6.1.1.1.1 Component Selection

Select components that are compatible with and rated for the viscosity of the hydraulic fluid to be used.

6.1.1.2 Cycling

Cycling capability for safety-critical components with the exception of metallic pressure vessels and COPVs as specified in ANSI/AIAA S-080-1998 and ANSI/AIAA S-081A-2006 shall be not less than four times the total number of expected cycles, including system tests, but not less than 2000 cycles (including the life factor of four). For service above a temperature of 160° F, an additional cycling capability equivalent to the above shall be required as a minimum.

6.1.1.3 Actuators

Safety critical hydraulic actuators shall have positive mechanical stops at the extremes of safe motion.

6.1.1.4 Shutoff Valves

Hydraulic fluid reservoirs and supply tanks shall be equipped with shutoff valves, operable from a relatively safe location in the event of a hydraulic system emergency.

6.1.1.5 Variable Response

Shuttle valves shall not be used in safety-critical hydraulic systems where the event of force balance on both inlet ports may occur, thus causing the shuttle valve to restrict flow from the outlet port.

6.1.1.6 Fire Resistant Fluids

Fire resistant or flame proof hydraulic fluid shall be used where system leakage can expose hydraulic fluid to potential ignition sources or where the system is adjacent to a potential fire zone and the possibility of flame propagation exists.

6.1.1.7 Accumulators

Hydraulic systems incorporating accumulators shall be interlocked to either vent or isolate accumulator fluid pressure when power is shut off.

6.1.1.8 Adjustable Orifices

Adjustable orifice restrictor valves shall not be used in safety-critical hydraulic systems.

6.1.1.9 Lock Valves

When two or more hydraulic actuators are mechanically tied together, only one lock valve shall be used to hydraulically lock all the actuators. Hydraulic lock valves shall not be used for safety-critical lockup periods likely to involve extreme temperature changes, unless fluid expansion and contraction effects

are safely accounted for.

6.1.1.10 Hydraulic Reservoir

Whenever possible, the hydraulic reservoir shall be located at the highest point in the system. If this is not possible in safety-critical systems, procedures must be developed to detect air in actuators or other safety-critical components and to ensure that the system is properly bled prior to each use.

6.1.2 Pressure Limit

Hydraulic system installations shall be limited to a maximum pressure of 15000 psi.

Note: There is no intent to restrain development of systems capable of higher pressures; however, the employment of such systems must be proceeded by complete development and qualification that includes appropriate safety tests.

6.1.3 Cavitation

6.1.3.1 Inlet Pressure

The inlet pressure of hydraulic pumps in safety-critical systems shall be specified to prevent cavitation effects in the pump passage or outlets.

6.1.3.2 Fluid Column

Safety critical hydraulic systems shall have positive protections against breaking the fluid column in the suction line during standby.

6.1.4 Hydraulic Lockup

6.1.4.1 Emergency Disengage

Hydraulic systems that provide for manual takeover shall automatically disengage or allow bypass of the main hydraulic system upon the act of manual takeover.

6.1.4.2 Emergency By-Pass

Safety-critical hydraulic systems or alternate bypass systems provided for safety shall not be rendered inoperative because of back-pressure under any set of conditions. Design the system so that a hydraulic lock resulting from an unplanned disconnection of a self-seating coupling or other component shall not cause damage to the system or to adjacent property, or injury to personnel.

6.1.5 Pressure Relief

6.1.5.1 Pump Pressure Relief

Hydraulic systems employing power-operated pumps shall include a pressure-regulating device and an independent safety-relief valve.

6.1.5.2 Thermal Pressure Relief

Thermal-expansion relief valves shall be installed as necessary to prevent system damage from thermal expansion of hydraulic fluid, as in the event of gross overheating. Internal valve leakage is not considered an acceptable method of providing thermal relief. Thermal relief-valve setting shall not exceed 150 psi above the value for system-relief valve setting. Vents shall outlet only to areas of relative safety from fire hazard. Hydraulic blowout fuses shall not be used in systems having temperatures above 160° F.

6.1.5.3 Location

Pressure-relief valves shall be located in hydraulic systems wherever necessary to ensure that the pressure in any part of a power system shall not exceed the safe limit above the regulated pressure of the system.

6.2 Pneumatic System Requirements

6.2.1 Pneumatic System Components

6.2.1.1 Component Integrity

Pneumatic components (other than pressure vessels) for safety critical systems shall exhibit safe endurance against hazardous failure modes for not less than four times the total number of expected cycles including system test. Pneumatic ground-support emergency system components shall have safe endurance of a minimum of 5000 cycles.

6.2.1.2 Configuration

The configuration of pneumatic components shall permit bleeding of entrapped moisture, lubricant, particulate material, or other foreign material hazardous to this system.

6.2.1.3 Compressors

Compressors shall be designed to sustain not less than 2.5 times the delivery pressure, after allowance for loss of strength of the materials equivalent to not less than that caused by 1000 hours aging at 275° F.

6.2.1.4 Actuators

Safety critical pneumatic actuators shall have positive mechanical stops at the extremes of safe motion.

6.2.1.5 Adjustable Orifice Restrictors

Adjustable orifice restrictor valves shall not be used in safety-critical pneumatic systems.

6.2.2 Controls

6.2.2.1 Manual Takeover

Provide for automatic disengagement or bypass for pneumatic systems that provide for manual takeover in the event of a hazardous situation. Provide positive indication of disengagement.

SMC Standard Improvement Proposal		
INSTRUCTIONS 1. Complete blocks 1 through 7. All blocks must be completed. 2. Send to the Preparing Activity specified in block 8. NOTE: Do not be used to request copies of documents, or to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements. Comments submitted on this form do not constitute a commitment by the Preparing Activity to implement the suggestion; the Preparing Authority will coordinate a review of the comment and provide disposition to the comment submitter specified in Block 6.		
SMC STANDARD CHANGE RECOMMENDATION:	**1. Document Number**	**2. Document Date**
3. Document Title		
4. Nature of Change (Identify paragraph number; include proposed revision language and supporting data. Attach extra sheets as needed.)		
5. Reason for Recommendation		
6. Submitter Information		
a. Name	**b. Organization**	
c. Address	**d. Telephone**	
e. E-mail address	**7. Date Submitted**	
8. Preparing Activity	Space and Missile Systems Center AIR FORCE SPACE COMMAND 483 N. Aviation Blvd. El Segundo, CA 91245 Attention: SMC/EAE	